Acknowledgement	This article may not exactly replicate the final published article. It is not the copy of the record. *Psychological Science*, *25*(5), 1059-1066
Archived version	Author manuscript: post-print (post-refereeing)
Published version	http://dx.doi.org/10.1177/0956797613519110
Journal homepage (Copyright)	http://www.uk.sagepub.com/journals/Journal201962 ISSN: 0956-7976, ESSN: 1467-9280
Author contact at KU Leuven	sibylle.petersen@ppw.kuleuven.be

(article begins on next page)

Categorical interoception:

Perceptual organization of sensations from inside

Sibylle Petersen[1], Mathias Schroijen[1], Christina Moelders[2], Sebastian Zenker[3], & Omer Van den Bergh[1]

1) KU Leuven, Department of Psychology

2) University of Hamburg, Department of Psychology

3) University of Hamburg, Department of Marketing

Corresponding author address: Sibylle Petersen, Tiensestraat 102, 3000 Leuven, Belgium,

sibylle.petersen@psy.kuleuven.be

Abstract

Accurate perception of bodily sensations is essential to protect health. However, misperception and misinterpretation of signals from within the body are common and can be fatal, for example in asthma or cardiovascular disease. We suggest that placing interoceptive stimuli into interoceptive categories (e.g., symptoms vs. benign sensations) leads to perceptual generalization effects which may underlie misinterpretation. In two studies, we presented stimuli inducing respiratory effort (respiratory loads) organized into categories vs. located on a continuous dimension. We found pervasive effects of categorization on magnitude estimations, on measures of affective stimulus evaluation, on stimulus recognition, and on breathing behavior. Results advocate for opening a new perspective in interoception which includes basal cognitive processes of stimulus organization to understand interoceptive bias. They are relevant to a wide range of interoception-related phenomena ranging from emotion to symptom perception.

Key words: categorization; assimilation; interoception; affect; dyspnea

Introduction

Health is not “une vie dans le silence des organes” (Valéry, 1942)[1]. In disease and in health, we are continuously exposed to a wide range of signals from our body such as breathing sensations, heart rate, gastro-intestinal sensations and so forth. Early and accurate detection of signs of pathology is of vital importance for health. However, misperception and misinterpretation of bodily sensations are common in chronic and acute conditions (e.g., stroke, myocardial infarction, asthma), sometimes with life threatening consequences (e.g., Banzett, Dempsey, O'Donnell, & Wamboldt, 2000; Mandelzweig, Goldbourt, Boyko, & Tanne, 2006).

Bias in interoception has typically been conceived as resulting from (motivated) inattention or hypervigilance to bodily sensations and from erroneous illness beliefs affecting the interpretation of bodily sensations towards excessively safe or dangerous (Petersen, van den Berg, Janssens, & Van den Bergh, 2011). However, we assume that more fundamental perceptual processes underlie misinterpretation. As in the perception of stimuli outside the body (exteroception), the perception of stimuli originating inside the body (interoception) can be organized by representing sensations as groups of stimuli (e.g., symptom categories) or on continuous dimensions (e.g. breathing effort, Petersen, Orth, & Ritz, 2008). Stimulus grouping is (usually) based on the assumption that class members are sufficiently similar to be treated the same and sufficiently different from members of other groups to be treated differently. Assigning a sensation, for example, to either the category “asthma symptoms” or the category “benign respiratory sensations” may start a cascade of top down processes which modulate the very perception of a stimulus (Petersen et al., 2011), whereas not assigning a sensation to a category (i.e., dimensional representation) may reduce such a perceptual bias.

[1] a live lived in the silence of organs

Little is known on effects of categorization on interoception. However, categorization effects have received extensive attention in other fields of psychology. Grouping of stimuli (i.e., Gestalt formation, Wertheimer, 1912) plays a crucial role in the perceptual process (for a review on traditional and “neo-Gestalt Psychology” see Wagemans et al., 2012) because categories provide “maximum information with least cognitive effort” (Rosch, 1978, p.28). They allow making inferences about unobserved features of a stimulus based on class membership (Lewandowsky et al., 2002), and gaining expertise on recognizing and differentiating stimuli (Gillebert, Op de Beek, Panis, & Wagemans, **2009**). However, the simplification that contributes to smooth perception can easily turn into overgeneralization. Even if category members are equally similar to each other than to non-category members (i.e., even if categorization does not relate to similarities and differences between stimuli in a meaningful way), categorization can lead to an increase in perceived similarity within classes (assimilation) and/or increase of perceived differences between classes (accentuation). These effects occur in visual perception (Corneille et al., 2002; Goldstone, 1995; Tajfel & Wilkes, 1963), perception of syllables (Campbell, 1956), or haptic evaluation of objects (Gaißert, Buelthoff, & Wallraven, 2011), showing that the mere knowledge of stimuli being located within categories (vs. seeing the stimuli grouped in a category/Gestalt) is sufficient to change perception (see also Gillebert et al., 2009).

However, results from exteroception may not be generalized to interoception in a one to one approach. Interoception differs from exteroception in important ways. Interoception is private, and the distal stimulus (located inside of the body) cannot be shared with others. As a consequence of this privacy, there is no objective standard for perceiving, for example, too much or too little breathlessness or pain in response to a stimulus. Furthermore, onset and location of bodily sensations are often ambiguous which is in contrast to most exteroceptive stimuli. Lack of objective standards and the increased ambiguity of stimuli should rather increase categorization effects since categorical information is more influential when uncertainty is high (Corneille et al., 2000). This assumption, however, has not been tested despite the fact that a categorical approach in diagnostics (e.g., asking for symptom categories) is more common than a dimensional approach.

Another fundamental difference between exteroceptive stimuli used in prior research and interoceptive stimuli is that interoceptive stimuli are tightly connected to emotions and physiology (Dunn et al., 2010). Internal sensations may easily act as alarm signals, turning them into affectively loaded and highly self-relevant stimuli. Indeed, positive or negative affect elicited by interoceptive sensations might serve as basis for categorization of sensations into affective categories (Brunner, Goodnow, & Austin, 1956; Niedenthal, Innes-Ker, & Halberstadt, 1999). However, the vast majority of research on the role of categorization in perception has studied exteroceptive stimuli low in complexity, low in self-relevance, and of neutral valence (e.g. line drawings, Corneille et al., 2002; Gillebert et al., 2009; Tajfel & Wilkes, 1963). Whether affect and self-relevance of interoceptive stimuli might interfere with basic cognitive processes and possibly influence categorization bias has received little attention. Moreover, the self-relevant affective component of categorizing an interoceptive stimulus may induce motivational tendencies which may be reflected in behavior towards this stimulus. Thus, using interoceptive stimuli allows studying fundamental processes in interoception and it also gives an opportunity for a direct test of the effect of categorization on affect and behavior.

The studies presented here test effects of categorical structure on the perception of breathing. We chose breathing as interoceptive domain because the feeling of breathing effort can be induced in different degrees of intensity which allows creating categories on a continuous effort dimension while being less aversive than, for example, pain. In Study 1, we tested the effect of categorization on basic magnitude estimations and on affective evaluation of respiratory stimuli assigned to categories labeled A and B. In the supplemental online material, we present a study that is also addressing the effect of categorization on affective evaluation with implicit measures, which confirms and extends results of Study 1. In Study 2, we tested whether categorization changes stimulus recognition and behavior involved in coping with respiratory stimuli.

Study 1

Participants

Sixty-two participants (20 male) without known respiratory disease were randomly assigned to an experimental group (n=32, mean age 23.7 years, *SD*=4.4) and a control group (n=30, mean age 22.1 years, *SD*=2.4). Participants were invited via internet platforms and flyers. All participants gave informed consent at the start of the experiment. The protocol was approved by the local ethics committee.

Instruments

We manipulated breathing effort by switching valves (respiratory loads, Threshold IMT, Respironics Inc.) into a breathing circuit. Six loads increased inspiratory resistance by a constant factor of 0.4 (7, 10, 14, 20, 28, 40 cmH_2O). The lowest load was well above the average perceptual threshold (Petersen & Ritz, 2010). Following Weber's law which also applies to respiratory stimuli (Wiley & Zechman, 1966), higher background noise increases perceptual thresholds. In breathing through respiratory loads, this "noise" is internal airway resistance (R_{int}) which can be increased by chronic (asthma) or acute (cold) conditions. We measured and controlled statistically for R_{int} (MicroRint, Micro Medical). Ratings of intensity and unpleasantness of respiratory sensations were given on Visual Analog Scales (VAS, 1-100) presented on a computer screen. Participants completed questions on age, gender, and respiratory disease.

Experimental protocol

Participants completed three blocks of load presentations **(Table 1)**. We presented each load 6 times per block resulting in 108 load presentations. Participants in both groups were asked to breathe in and out two times through the load before rating intensity and unpleasantness. In Block I, loads were presented to both, experimental and control group in ascending order without category information (Loads 1-6 followed again by Loads 1-6). In Block II, loads were presented in ascending order and participants in the experimental condition were instructed that Loads 1-3 belonged to Category A and Loads 4-6 belonged to Category B. Participants in the control group did not receive information on categories, but in this group Block II was identical to Block I. In Block III, loads were presented in random order (using the online program Research Randomizer (Urbaniak & Plous, 2011) to create random order of 6 loads in six separate random presentation blocks). In the experimental group, instructions in Block III reminded participants that Loads 1-3 belonged to A and Loads 4-6 to B.

Table 1: Labels for respiratory loads and order of load presentation for experimental and control group

		Block I	Block II	Block III
Order		Ascending	Ascending	Random
Experimental Group	Labels	Load 1, Load 2, Load 3, Load 4, Load 5, Load 6	A1, A2, A3 B1, B2, B3	A1, A2, A3 B1, B2, B3
Control Group	Labels	Load 1, Load 2, Load 3, Load 4, Load 5, Load 6	Load 1, Load 2, Load 3, Load 4, Load 5, Load 6	Load 1, Load 2, Load 3, Load 4, Load 5, Load 6

Data analysis

We used the software SPSS 18 for all analyses. We calculated percentage of perceived increase between adjacent loads in intensity and unpleasantness and calculated aggregated within-category similarity as mean perceived increase between Load 1 and 2 and 2 and 3 (within A) and load 4 and 5 and 5 and 6 (within B). Between-category differences were calculated as percentages of perceived difference between load 3 and 4.

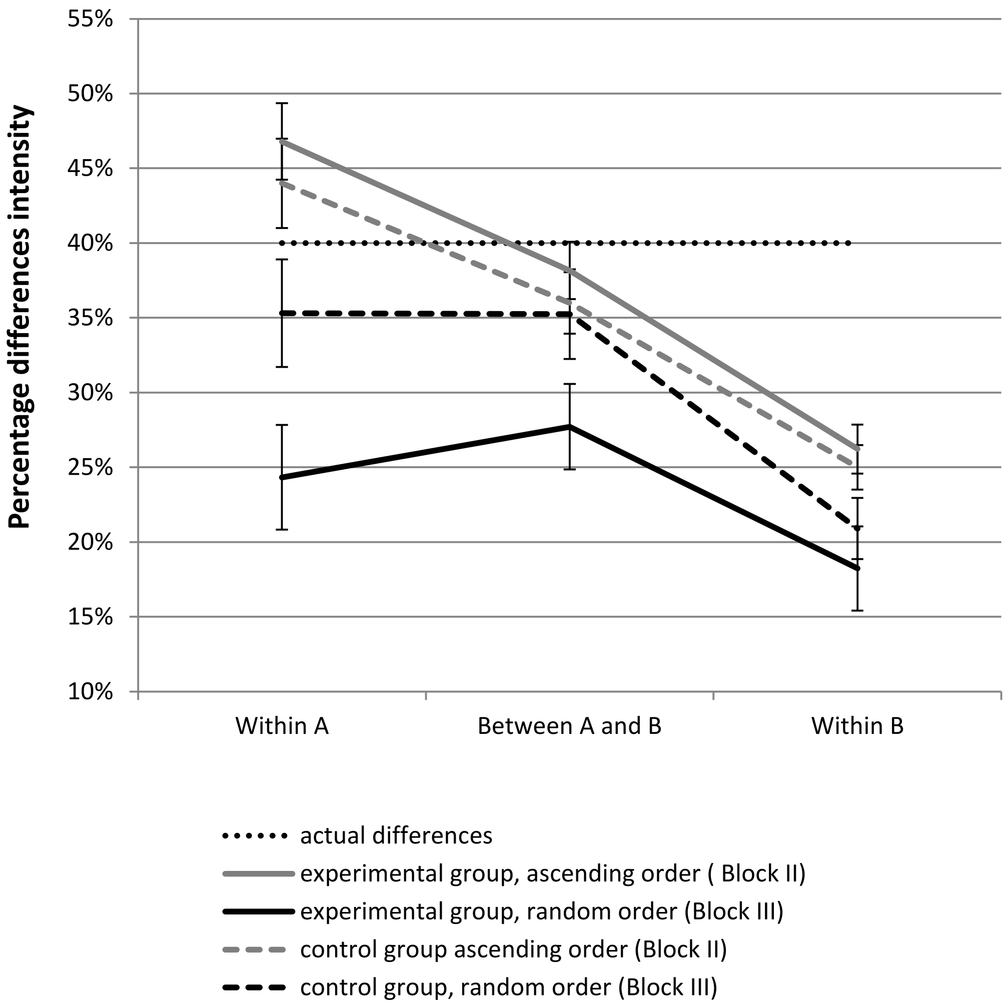
For each of the three blocks, we tested effects in repeated measures ANOVAs with the 3 levels of the within-individual variable: (1) differences within A, (2) differences between A and B, (3) differences within B. The two levels of the between-individual variable were experimental and control group. We tested for assimilation effects, that is, increases in perceived similarity within categories (a) relative to the control condition without categorization and (b) relative to between-category differences. For post-hoc tests of assimilation relative to Block I (no categorization), we used paired sample *t*-tests. As post-hoc test for assimilation effects (increased similarity within categories) relative to between-category differences, we tested (for each Block separately) a quadratic within-individual contrast. We included respiratory resistance as covariate. Partial eta² (η^2_p) was the measure of effect size.

Results

We found significant effects of organizing loads into categories versus dimensional organization for intensity and unpleasantness ratings, but only under random order presentation (Figure 1a and 1b). For the sake of clarity, we omitted Block I in Figures 1a and 1b since these values do not differ significantly from their respective values in Block II. In Block III (random order), but not in Block II (ascending order) within-class similarity was greater relative to between-class differences, quadratic within-individual contrast intensity $F(1,30)=20.45$, $p<.001$, $\eta^2_p=.405$, unpleasantness $F(1,30)=14.33$, $p=.001$, $\eta^2_p=.323$. Furthermore, in the experimental group, assimilation effects relative to Block I and II were significant, that is, differences within A and within B were lower in Block III than in Block I and II (all *p*s<.023). Perceived between-class differences were not greater than actual differences (40% increases in resistance) or differences in Block I or II or in the control group, that is, accentuation was only found relative to within-category similarity.

We did not find an interaction effect of Group x Within-individual variable for perceived differences, $F(2,57)=.585$, $p=.560$. This lack of interaction was due to a significant decrease in perceived difference for higher compared to lower loads regardless of group and experimental block, main effects Block I-III intensity $F(2,59)>5.14$, $p<.007$, $\eta^2_p>.080$, unpleasantness $F(2,59)>2.53$, $p<.090$, $\eta^2_p>.041$. Higher loads were perceived to be more similar than lower loads in all three blocks, obscuring group differences in assimilation effects. However, control group and experimental group differed significantly in perceived differences within Category A in the random order condition, intensity $p=.036$, discomfort $p=.047$. In in accordance with our hypothesis, we found a significant quadratic effect only in the experimental group (see above), but not in the control group, $F(2,57)=.279$, $p=.608$.

1a


55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
Percentage differences intensity
Within A
Between A and B
Within B
actual differences
experimental group, ascending order (Block II)
experimental group, random order (Block III)
control group ascending order (Block II)
control group, random order (Block III)

1b

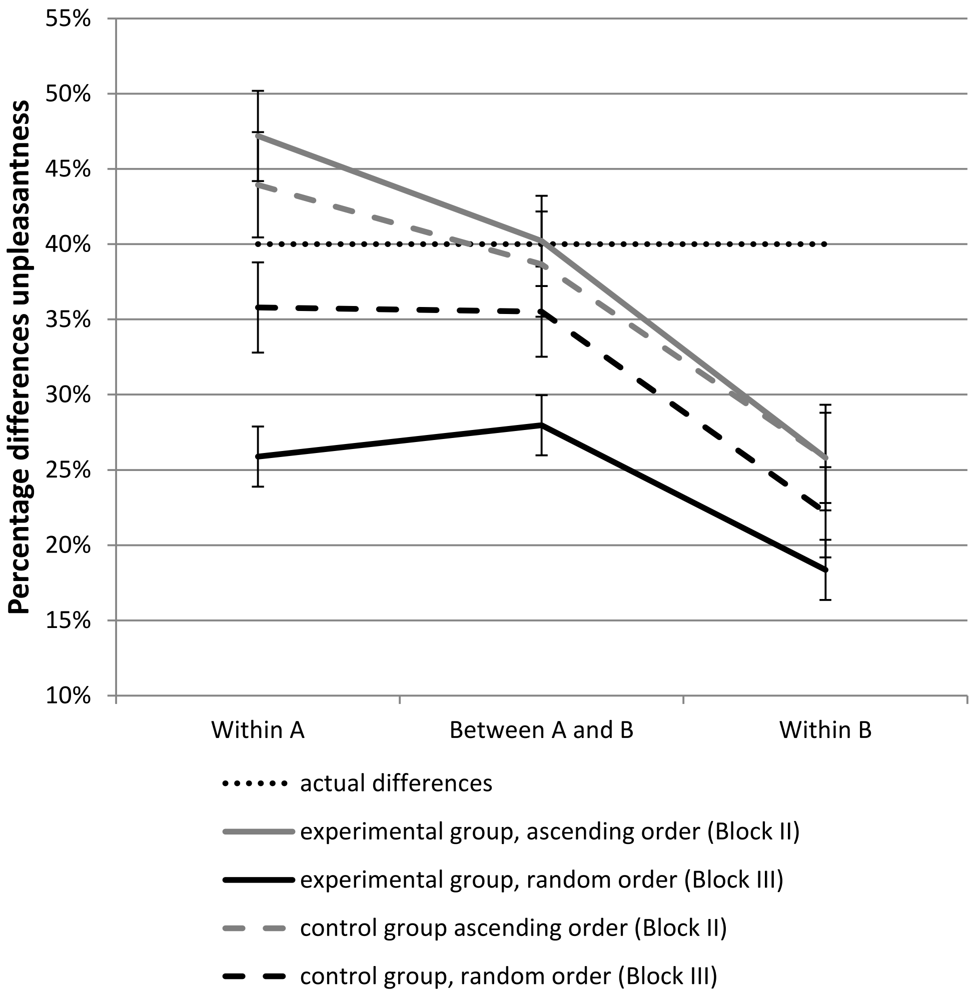


Figure 1: Differences within and between categories in the experimental group (bold lines) and control group (dotted lines) for (a) intensity and (b) unpleasantness. Block I (ascending order presentation, no information on categorization in either groups) is omitted for the sake of clarity. Error bars represent standard errors of the mean.

However, looking at raw values (i.e., absolute magnitude of intensity and unpleasantness ratings), we find a significant interaction effect of Category by Experimental Group, intensity $F(2,59)=6.76$, $p=.012$, $\eta^2_p=.101$, unpleasantness $F(2,59)=6.12$, $p=.016$, $\eta^2_p=.093$. Again, accentuation was significant only relative to within-category similarities of the same experimental block (Block III, quadratic effect), but not relative to the no-categorization block (Block I). This assimilation within categories combined with a lack of accentuation in comparison to the control group resulted in significantly higher absolute values in Category A and significantly lower values in Category B in the experimental group. In other words, for absolute values, we find an interaction of Group by Category, reflecting more moderate ratings of load magnitude and unpleasantness under categorization.

When airway resistance R_{int} was introduced as covariate in the model on perceived similarities, it interacted significantly with the within-individual factor in Block III, but only in the experimental group, intensity $F(1,30)=16.67$, $p<.001$, $\eta^2_p=.357$, unpleasantness $F(2,29)=11.88$, $p=.002$, $\eta^2_p=.284$ (control group all Fs<1). To illustrate these findings, we calculated one mean assimilation score for Block III by subtracting mean within-category differences from between-category differences. In the experimental group, higher R_{int} was related to lower effects, intensity $r(32)=-.598$, $p<.001$, unpleasantness $r(32)=-.533$, $p<.001$ (control group $p>.158$ for both relationships).

Discussion Study 1

Grouping of stimuli in categories affected self-report of intensity and unpleasantness of breathing, but only if loads were presented in random order. Results confirm prior research showing that higher uncertainty about a stimulus (as given under random order) is associated with greater influence of category information (Corneille et al., 2002).They extend results from prior research in showing that categorization (under random order presentation) also increased similarities in affective evaluation. However, we did not find accentuation effects, that is, we do not find higher within category similarity compared to between category similarity, but only increased within category similarity. In Study 1.2 (supplemental online material), we confirm results of Study. We find categorization effects in ratings of intensity and unpleasantness, but only if stimuli were presented in random order. Importantly, in the study in the supplemental material, we find categorization effects in affective evaluation in self-report as well as in an alternative, implicit measure.

Since category labels were neutral and did not provide an anchor point inducing either over **perception** or under perception, we found reduction in extremity of ratings under this neutral categorization. This highlights that bias induced by categorization (increased perceived similarity) is not necessarily related to over perception or under perception as such. Direction of deviation in interoceptive accuracy may strongly depend on category labels serving as information and anchor points.

The impact of airway resistance on results is interesting. Physiological background noise should not be related to a re-anchoring of self-report, but it affects perception on a sensory level. The present study did not allow testing whether effects of categorization were merely post-hoc effects of re-anchoring self-report according to the category prototype/mean. In Study 2, we used measures that were not dependent on self-report of magnitude estimates and unpleasantness. Instead, we calculated confusion frequencies between loads as measure of similarity (Shepard, 1987) and assessed breathing behavior (inspiratory flow, i.e., liter air inhaled per second). Flow rates are directly related to respiratory effort (e.g., breathing through a straw gets harder the faster we try to suck air through the straw). Adjusting flow can be interpreted as part of coping with a respiratory load.

Study 2

Participants

Participants were 30 individuals (10 male, mean age = 19.4, *SD*=1.7) without known respiratory diseases (self-report). Participants were invited via flyers and internet platforms. All participants gave written informed consent. The protocol was approved by the local ethics committee.

Instruments

We used an electronic device that manipulates breathing resistance and allows measuring inspiratory flow (l/s) breath by breath (Breathelink K5, HaB Inc.). We presented 8 different loads categorized in A (6, 9, 12, and 16 cmH_2O) and B (21, 28, 37, and 49 cmH_2O). We assessed positive and negative affect with the PANAS (Watson et al., 1988).

Protocol

At the start of the respiratory task, participants were informed that loads were categorized in A (loads 1-4) and B (loads 5-8). In Block I, we presented each load four times for two breaths and measured inspiratory flow breath by breath. Before each presentation, participants saw the label of the loads (A1, A2, A3, A4, B1, B2, B3, or B4) on the computer screen and were asked to memorize breathing experiences and label. In Block II, loads were presented in random order (across all load presentations and not in blocks of loads as in Study 1) for two breaths per load four times, but this time participants had to type in the labels of the loads (A1-B4). After this task, participants completed the PANAS and demographic questions.

Data analysis

We calculated mean inspiratory flow across the two breaths of each load presentation. We calculated percentage of difference in inspiratory flow between adjacent loads. Furthermore, we calculated mean confusion frequencies. Two stimuli can be regarded to be similar to the extent that they evoke the same response, that is, to the extent that they are confused, relative to correct identifications (Shepard, 1987). This measure of generalization can be expressed as $g_{ij} = [(p_{ij}*p_{ji})/(p_{ii}* p_{jj})]^{1/2}$ with p being the likelihood of correctly identifying or confusing stimuli i and j.

Results

Categorization changed breathing behavior and led to assimilation in respiratory flow in Block I (Figure 3). Differences within categories were significantly smaller than between categories, quadratic contrast $F(1,29)=8.49$, $p=.007$, $\eta^2_p=.226$, main effect $F(2,28)=7.17$, $p=.002$, $\eta^2_p=.198$.

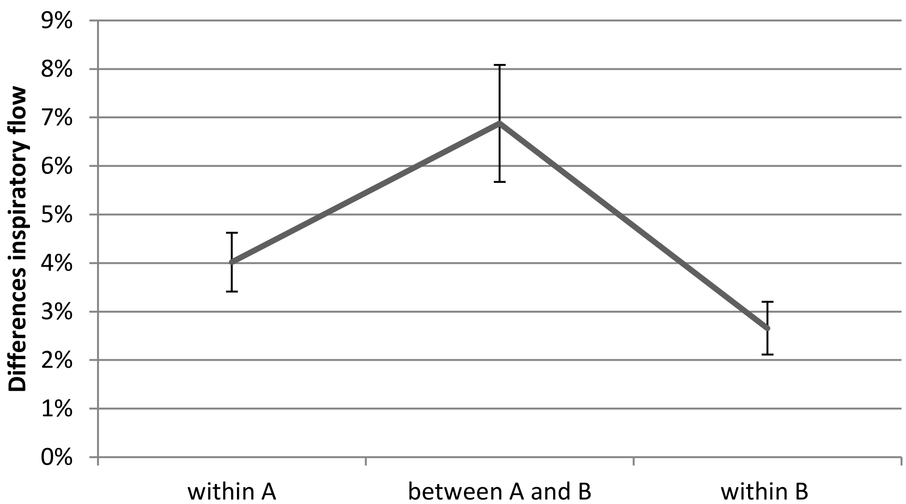


Figure 2: Differences in inspiratory flow within Category A, between AB, and within Category B. Error bars represent standard errors of the mean.

Loads were confused more often within than between categories (Figure 4, quadratic contrast $F(1,29)=65.52$, $p<.001$, $\eta^2_p=.693$, main effect $F(2,28)=43.94$, $p<.001$, $\eta^2_p=.602$). In both behavioral measures, positive or negative affect did not have an impact on results, *Fs*<1.

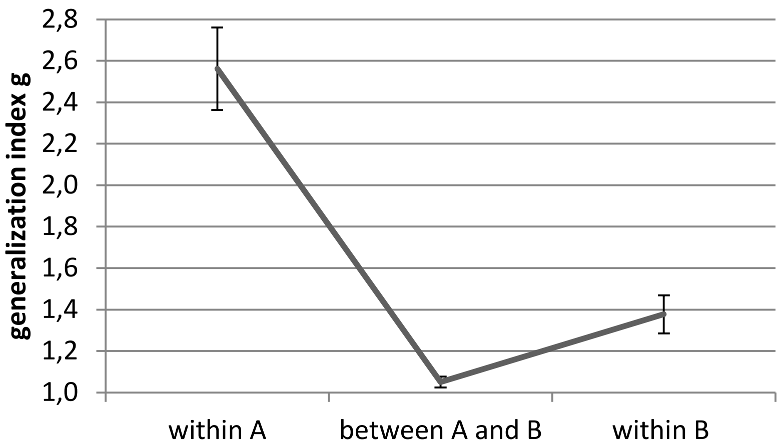


Figure 3: Confusion frequencies within Category A, between boarders of A and B and within Category B. Higher values represent higher similarity. Error bars represent standard errors of the mean.

General discussion

Categorization of interoceptive sensations changes perception of their magnitude and unpleasantness, it changes stimulus recognition, and it changes coping behavior towards these stimuli. These effects occur even when categorization is based on abstract labels (A and B), representing “less intense” and “more intense”. However, we found a significant quadratic effect indicating larger within-category relative to between-category differences only when the constant increase between stimuli was obscured by random presentation (Study 1). These results mirror findings that uncertainty about stimuli increases the value of category information and, thus, categorization effects (Corneille et al., 2002).

Importantly, findings with confusion frequencies and inspiratory flow suggest that categorization effects in interoception (and probably also in exteroception) reflect not merely post-hoc changes in self-report. In contrast to self-report (Study 1), voluntary adjustment of confusion frequencies or inspiratory flow to reflect category membership of a stimulus is (while not being impossible) exceedingly more difficult than voluntary adjustment of self-report to make ratings match a category label. Our results suggest that categorization effects are more likely to be found under increased uncertainty about stimulus magnitude (or other stimulus characteristics) and when the response to the stimulus is reflecting more automatic and less voluntarily controlled processes. Research working with self-reported stimulus evaluation alone might underestimate the impact of categorization on affect and behavior.

An important finding of Study 1 and 2 (and of Study 1.2 in the supplemental online material) is that categorization also has an impact on affective stimulus evaluation and behavior directed towards stimuli. In classical studies in social cognition research on categorization effects, stimuli are mostly of neutral valence (lines, colors, or shapes, e.g., Corneille et al., 2002; Goldstone, 1995; Tajfel & Wilkes, 1963), and assessing affective evaluation and behavioral measures is of little relevance. Nevertheless, these classical experiments are used as theoretical basis for more applied research on prejudices, that is, affectively loaded psychological phenomena which can have relevant behavioral consequences. The studies here contribute to closing a gap in research and theory development, demonstrating that categorization leads individuals not only to *think* more similar about stimuli, but also to *feel* more similar about them, and to *approach* them in a more similar way.

Results also suggest that categorization is important for emotion perception. Most signs of increased physiological activation (heartbeat, visceral sensations, etc.) are unspecific and similar for positive and negative emotions. Strong bodily sensations experienced, for example, during a roller coaster ride can be interpreted as either signs of intense enjoyment or signs of the start of an asthma attack, depending on how much a person likes to take a ride (Rietveld & van Beest, 2007). Ambiguity of interoceptive sensations in emotion perception requires categorization to select coping strategies. At the same time, it opens the door for increasing similarity of affective interpretation and potentially more similar emotions. If, as our results suggest, categorization impacts affective evaluation and emotions, perceptual re-organization of stimuli from categories towards the perception of individual stimuli or stimulus dimensions might reduce bias in affective evaluation as much as recategorization and decategorization have been shown to reduce bias in other fields of psychology, for example, intergroup bias (Gaertner, Mann, Murrell, & Dovidio, 1989).

Categorization effects in interoception are highly relevant for the clinical context. Priming categories such as symptoms rather than sensations, as is done in most medical consultations and by most diagnostic instruments, may alter the perception of the intensity of one's internal sensations, affective evaluation, and behavioral coping. Emphasizing the dimensional character of sensations by asking how much breathing is changed on an effort dimension (vs. asking whether symptoms are present) can increase bottom-up processing and reduce bias with beneficial outcomes for diagnostics and disease (self-)management.

Limitations

Results found in healthy individuals should not be generalized to patients having detailed and complex pre-existing knowledge structures about their illness, and results found with a breathing manipulation should not be readily generalized to all interoceptive sensations.

We used symmetrical categories (as e.g., Tajfel & Wilkes, 1963), but effects might increase if participants are allowed to choose cut-off points or if categories are asymmetrical. Furthermore, we did not use more than two categories, since we could not increase load strength infinitely and wanted to keep loads distinguishable. Moreover, future studies should explore different measures of assimilation (see e.g., Park & Judd, 1990). We found small effects of positive affect on results with implicit measures in Study 1.2 (supplemental online material), but further research is necessary inducing higher levels of positive and negative affect to explore the interaction of categorization with affect.

Conclusion

The organization of bodily sensations in categories can bias interoception. Categorization as a perceptual organization process precedes and underlies affective evaluation, cognitive elaboration and coping behavior in interoception.

Acknowledgements:

This research was funded by the Research Foundation Flanders. The authors thank Anne Koehler and Elina Schuermann for their help in data acquisition and data preparation for the analysis of flow (breath by breath) in Study 3.

Author contributions:

S.P. developed the study concept. All authors contributed to the study design. Testing and data collection were performed by S.P., C.M., S.Z. and M.S. and S.P. performed the data analysis and interpretation under the supervision of O.V.D.B. S.P. drafted the paper, and all authors provided critical revisions. All authors approved the final version of the paper for submission.

References

Banzett, R.B., Dempsey, J.A., O'Donnell, D.E., & Wamboldt, M.Z. (2000). Symptom perception and respiratory sensation in asthma. *American Journal of Respiratory and Critical Care Medicine*, 162, 1178-1182.

Bruner, J. S., Goodnow, J. J., & Austin, G. A. (1956). A study of thinking. New York: Wiley.

Campbell, D.T., 1956. Enhancement of contrast as composite habit. *Journal of Abnormal and Social Psychology, 53*, 350–355.

Corneille, O., Klein, O., Lambert, S., & Judd, C.M. (2002). On the role of familiarity with units of measurement in categorical accentuation: Tajfel and Wilkes (1963) revisited and replicated. *Psychological Science*, 4, 380-383.

Dunn, B. D., Galton, H. C., Morgan, R., Evans, D., Oliver, C., Meyer, M., Cusack, R., Lawrence, A. D., & Dalgleish, T. (2010). Listening to your heart. How interoception shapes emotion experience and intuitive decision making. *Psychological Science, 21*, 1835-1844.

Gaertner, S. L., Mann, J., Murrell, A., & Dovidio, J. F. (1989). Reducing intergroup bias: The benefits of recategorization. *Journal of Personality and Social Psychology, 57*, 239-249.

Gaißert, N., Buelthoff, H. H., & Wallraven, C. (2011). Similarity and categorization: From vision to touch. *Acta Psychologica*. [Epub ahead of print].

Gillebert, C.R., Op de Beeck, H.P., Panis, S., & Wagemans, J. (2009). Subordinate categorization enhances the neural selectivity in human object-selective cortex for fine shape differences. *Journal of Cognitive Neuroscience*, 21, 1054-1064.

Goldstone, R.L. (1995). Effects of categorization on color perception. *Psychological Science*, *6* , 298-304.

Lewandowsky, S., Kalish, M., & Ngang, S.K. (2002). Simplified learning in complex situations: Knowledge partitioning in function learning. *Journal of Experimental Psychology: General,* 131, 163–193.

Mandelzweig, L., Goldbourt, U., Boyko, V., & Tanne, D. (2006). Perceptual, social, and behavioral factors associated with delays in seeking medical care in patients with symptoms of acute stroke. *Stroke, 37*, 1248-1253.

Niedenthal, P. M., Halberstadt, J. B., & Innes-Ker, A. H. (1999). Emotional Response Categorization. *Psychological Review, 106*, 337-361.

Park, B., & Judd, C. M. (1990). Measures and models of perceived group variability. *Journal of Personality and Social Psychology, 59*, 173-191.

Payne, B.K., Cheng, C.M., Govorun, O., & Stewart, B.D. (2005). An inkblot for attitudes: affect misattribution as implicit measurement. *Journal of Personality and Social Psychology, 89*, 277-293.

Petersen, S., Orth, B. & Ritz, T. (2008). Awareness of breathing: The structure of language descriptors of respiratory sensations. *Health Psychology, 27*, 122-127.

Petersen, S., Ritz, T. (2010). Situational self-awareness and report bias in the detection of respiratory loads in healthy individuals: over-report is linked to external focus. *British Journal of Health Psychology*, 15, 401-416.

Petersen, S., van den Berg, R., Janssens, T. & Van den Bergh, O. (2011). Illness and symptom perception: a theoretical approach towards an integrative measurement model. *Clinical Psychology Review, 31*, 428-439.

Rietveld, S., & van Beest, I. (2007). Rollercoaster asthma: when positive emotional stress interferes with dyspnea perception. *Behavioral Research & Therapy, 45*, 977-987.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization*. Hillsdale, NJ: Erlbaum. Reprinted in: Margolis, E. and Laurence, S. (Eds.) (1999). Concepts: Core readings. Cambridge, MA: MIT Press.

Scano, G., Stendardi, L., & Grazzini, M. (2005). Understanding dyspnoea by its language. *European Respiratory Journal, 25*, 380-385.

Shepard, R. N. (1987). Toward a universal law of generalization for psychological science. *Science*, *237*, 1317-1323.

Tajfel, H., & Wilkes, A.L. (1963). Classification and quantitative judgment. *British Journal* Journal *of Psychology*, *54*, 101–114.

Urbaniak, G. C., & Plous, S. (2011). Research Randomizer (Version 3.0) [Computer software].

Valéry, P. (1942). *Mauvaises pensées et autres*. Paris: Gallimard.

Wagemans, J., Elder, J.H., Kubovy, M., Palmer, S.E., Peterson, M.A., Singh, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure-ground organization. *Psychological Bulletin, 138*, 1172-1217.

Watson, D., Clark, L.A., & Tellegen, A. (1988). Development and validation of a brief measure of positive and negative affect. *Journal of Personality and Social Psychology, 54,* 1063–1070.

Wertheimer, M. (1912). Experimentelle Studien ueber das Sehen von Bewegung. *Zeitschrift fuer Psychologie*, *61*, 161–265. (Translated extract reprinted as “Experimental studies on the seeing of motion”. In T. Shipley (Ed.), (1961). Classics in psychology (pp. 1032–1089). New York, NY: Philosophical Library.).

Wiley, R. L., Zechman, F. W. Jr. (1966). Perception of added airflow resistance in humans. *Respiratory Physiology*, 67, 73-87.